

Antimicrobial Resistance: Public Health Call to Action

By

Lisa A McCarroll MHS, PA-C

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Advisor signature/printed name

Second Reader Signature/printed name

Date

Abstract

Antimicrobial resistance: what is the public health sector doing to address this increasing threat to the health of the entire world? This is a global threat, not one that impacts just the poor or underdeveloped nations. There appears to be more public recognition of the impact on the public health community, but the question is; has it been validated? Will funding be made available? What progress has been made for prevention and surveillance? Are we all talk and no action?

The Centers for Disease Control and Prevention (CDC) has defined the top ten greatest achievements of public health over the past century. In that list is control of communicable diseases, which includes the discovery, introduction and utilization of antimicrobial agents (Centers for Disease Control and Prevention (CDC), 2011). It is currently accepted that the most significant impact on the increase of human life expectancy can be attributed to Public Health practice and its achievements. Despite this, funding for public health practice and preventative measures is meager at best. Currently, fewer than two percent of health care dollars are utilized for Public Health Protection programs and measures.

In the early 1900s the principle causes of death were primarily infectious diseases. As we developed preventative measures, medical treatments and experienced decreased incidence, these causes plummeted down the list. Life expectancy increased substantially. However, we are again faced with the threat of increasing impact of infectious diseases on morbidity and human mortality. More microbes are evolving and developing resistance to the defenses that we have built against them.

An overview of current public health initiatives as well as the analysis of antimicrobial stewardship programs and their role in prevention and integration into public health leadership

will be reviewed and surmised in this report. In addition recommendations for further action will be discussed based on best practices determined in the current literature review.

Introduction

Antimicrobial resistance is not prejudicial or discriminatory in nature. It affects and impacts people irrespective of financial, social, power or educational status. It is all encompassing and, therefore, a public health threat! Although programs have been put into place for the prevention and control of antimicrobial resistance, universal governance and guidance would be more prudent to assure that best practices are being employed nationally and globally. Public health departments and leaders would be the most skilled and appropriate for such an endeavor.

Within the Twentieth century, public health was responsible for an increase in life expectancy of approximately 25 years in the United States (US). The CDC defines public health as: “the active protection of our nation’s health and safety, credible information to enhance health decisions, and partnerships with local minorities and organizations to promote good health” (Centers for Disease Control and Prevention (CDC), 2011). One of public health’s most significant contributions in infectious disease mortality reduction occurred with the advent of antibiotics. During this era, the discovery, development and support of extensive use of antibiotics, in conjunction with sanitation, hygiene and vaccination lead to a significant shift in the most prevalent causes of death (Centers for Disease Control and Prevention (CDC), 1999). In 1900 the leading causes of death were attributed to three infectious diseases: Tuberculosis, pneumonia, and diarrheal disease. Together they accounted for over one-third of the mortality in the United States. In comparison during 1997, infectious diseases were responsible for only four and a half percent of US mortality. This shift occurred shortly after the 1940s when penicillin was first

introduced to the public and accepted among the medical community (Centers for Disease Control and Prevention (CDC), 2011).

Despite the immediate and universal acceptance of antibiotics as amazing treatments of disease, it was not long after their introduction that microorganisms began to develop resistance, slowly increasing their threat to human life again (Davies, 1997). Over the years resistance has become more prevalent, and the successful introductions and use of new antimicrobials has decreased. We are now facing a time referred to as the “Post antibiotic Era” when antimicrobial resistance needs to be considered a public health emergency (Tenover & Hughes, 1996)!

Antimicrobial resistance is a multifaceted issue with several contributory causes. Resistance has primarily been attributed to the ability of microbes to adapt to their surrounding environment. Some data suggest that microbes may have already been preprogrammed for mutations, resulting in resistance long before the introduction of antimicrobials (Davies, 1997). In conjunction with microbes’ unique adaptive abilities, human behaviors have aided in the development of antimicrobial resistance, and have hastened the process over the years beyond what might have occurred in a natural setting. The uses - and more specifically - misuses of antimicrobials have been a major contributor to the resistance of microbes to many antimicrobials in use today. Unfortunately, improper use of antimicrobials is fairly common in both the hospital and the community setting. With that, there is the added misfortune of fewer antimicrobials coming to market each year (Cohen, 1992; Craig et al., 1978; Hecker, Aron, Patel, Lehmann, & Donskey, 2003a; Hecker, Aron, Patel, Lehmann, & Donskey, 2003b; Sunenshine, Liedtke, Jernigan, Strausbaugh, & Infectious Diseases Society of America Emerging Infections Network, 2004). This has led to an increase in mortality from what we now know as “super-bugs”. “Super bugs” have the ability to infect all walks of human life, not just those who are considered immuno-

suppressed. As incidence and prevalence increase across nations, we turn a corner heading back toward the days of the 1900s.

While the above realities have been recognized by many in the medical community, government and public health leadership, no direction as to who should take charge has been identified and what each person's role is. Slowly, endeavors are being launched in a war against resistance. The hope is that it will not be too late.

Public Health Policy

“Law is foundational to U.S. public health practice. Laws establish and delineate the missions of public health agencies, authorize and delimit public health functions, and appropriate essential funds,” wrote Goodman and colleagues (2006, p. 29). In 2011, the Institute of Medicine (IOM) published a report titled For the Public's Health: Revitalizing Law and Policy to Meet New Challenges. The IOM put together a committee to review three topics pertaining to public health: measurement, the law and funding. This task was at the request of the Robert Wood Johnson Foundation in 2009. For the purpose of this paper, current challenges and past successes of public health policy will be reviewed to demonstrate the challenges that are faced by the public health sector as well as identify successes and strengths within previous and current actions (Goodman et al., 2006; IOM (Institute of Medicine), 2011).

Most current public health laws are outdated. They were created in the late 19th and early 20th century and many of these statutes have not been updated in decades. In their time, they were backed by scientific evidence of that period. However the progression of determinants of health has continued to evolve since their adoption. In addition, many were created in the midst of a public health crisis or outbreak at the time, and are not reflective of our current circumstances.

This has resulted in fragmented and duplicative laws that are confusing, at the very least, to enact in today's day (IOM (Institute of Medicine), 2011; Meier, Hodge, & Gebbie, 2009).

Another consideration is the establishment of statutes enacted by other areas of government which have created unintended consequences. Subsidies paid to the agricultural communities led to the introduction of artificial sweeteners, creating nutrition-poor foods. Educational campaigns and the national education policy have created a stressed schooling system wherein the physical education of our youth has taken a minor role and in some areas is non-existent (IOM (Institute of Medicine), 2011).

Federal regulation of public health falls under the purview of the Department of Health and Human Services (HHS), which include the CDC and the FDA. Under the federal level are the state and local public health agencies. Relationships between the state and local agencies vary across the country and can be divided into three models: decentralized-local public health operating independently of the state and reporting solely to local government or local boards of health; centralized-regional public health agencies, not local and shared; and mixed authority models-public health agencies reporting to either the state or local governments. In the U.S., 29 states have decentralized public health agencies, six states and the District of Columbia have a centralized public health system and the remaining 13 have a shared and mixed model. The lack of consistency, nationally, makes it difficult to create universal governing of public health programs. A unified approach to national public health programs will decrease disparities in distribution of the positive effects of such programs. Additionally, a cohesive approach can expedite the success of programs addressing issues that cross regional borders. (Leep, 2006).

Both the state and local public health agencies typically share public health responsibilities with other governmental agencies and each state has its own set of public health laws. The complexity of public health's legal authority is beyond the scope of this paper, however the numerous variations across the nation creates concern that the development of public health programs aimed at national and global issues will face challenges in eliciting national cohesiveness. As stated previously, an issue such as antimicrobial resistance is not region specific and therefore will require cooperation and a unified front (IOM (Institute of Medicine), 2011).

Despite these challenges, our government has created several successful policies that improve population health. Some of these are successfully managed, primarily, by public health agencies. Food and drug labeling and the control of health information are managed by the FDA and HHS, respectively. Programs have been developed to decrease incidence in HIV transmission through clean needle programs and de-criminalizing HIV risk behaviors. Safety and prevention, such as seatbelt and helmet laws and water sanitation are also monitored and supported by public health agencies. Outside of the U.S., the United Kingdom (UK) successfully reduced their citizens' salt intake through a program started in 2003. The health authorities of the UK started working with food industry setting target goals of reduction through improved manufacturing of target foods. By 2010, it was noted that one major brand of chips contained 55% less sodium and the national average of salt intake fell from 9.5 grams in 2001 to 8.6 grams in 2010. The agency estimates that once the target goal of 6 grams of sodium intake a day is reached, they will have prevented 20,200 premature deaths per year. Indoor clean air acts have also been regulated by U.S. public health agencies and a decreased exposure to second hand smoke was able to show a reduction in hospital admissions for acute coronary syndromes within months of these acts being enforced

(Juster et al., 2007). The issue still remains concerning the inconsistency of public health agencies' ability to enforce prevention programs nationally (IOM (Institute of Medicine), 2011).

In 2007, the WHO supported the implementation of the International Health Regulations (IHR). One hundred and ninety-four state parties, including the United States, are involved in these efforts. The regulations are a legally binding set of health regulations that require participating agencies to enact a set of global rules that improve regional, national and global public health security. The IHR requires the reporting of specific disease outbreaks and significant public health threats to the WHO. The purpose of such actions is to limit the global spread of such tragedies and assist in their containment. The IHR also calls for participating countries to enhance and improve their public health surveillance systems, providing technical support as needed. The IHR provides current information for international travelers regarding current health threats and outbreaks. Through the IHR the WHO has published guidelines for member states to utilize in the development and implementation of laboratory activities, safety features, biochemical transportation and field investigation. Additionally through the IHR, a global alert system is in place to assist with international public health threats (World Health Organization, 2011).

In light of the rationale behind the development of the IHR, the threat of antimicrobial resistance has been broached as a possible responsibility for the IHR to tackle. Much debate still exists, although AR as a global threat is well known. Through the IHR, the WHO is required to provide surveillance and recommendations of any potential global public health threat. A global early warning system would assist in the prevention and control of AR. Barriers to such a system have been identified as political, technical and financial. For the WHO to be aware of a threat, they require notification. Many of the party states do not have the ability or technology to

comprehensively detect AR. In addition, notification may be thwarted by government agencies in an attempt to avoid blame for a potential outbreak. Finally, the WHO does not currently have the capability to track all resistant organisms (Wernli et al., 2011).

Literature Review of Antimicrobial Resistance and Public Health

In 1999 a congressional hearing on the issue "Antimicrobial Resistance: Solutions to a Growing Public Health Problem" resulted in the development of The Interagency Task Force on Antimicrobial Resistance (ITFAR). This task force brought together a variety of federal agencies to address the complex issue of antimicrobial resistance. These agencies included the CDC, Food and Drug Administration (FDA) and the National Institutes of Health (NIH). A total of 10 federal agencies currently comprise the task force (Centers for Disease Control and Prevention (CDC), 2011).

In 2001 the ITFAR drafted *A Public Health Action Plan to Combat Antimicrobial Resistance Part 1: Domestic Issues*. This publication was intended to be used as an outline for explicit federal actions to deal with antimicrobial resistance. This plan was the consensus of the ten federal agencies in the task force, with input from state and local public health officials, universities, healthcare organizations and many others invested in human health. In 2011, ten years after the initial report, the action plan was revised and publicized. These revisions brought the original plan more into focus, highlighting four key topic areas: surveillance, prevention and control, research and product development.

This revision also addresses the global issue of antimicrobial resistance (AR) and the evolving dynamics of AR over extended periods of time. Specifically this revision suggests that a global approach will address the introduction of new pathogens to different regions based on

international travel and modifications based upon resistance patterns. Changes to the ITFAR action plan will be published every two years, with annual updates given on the progress of current action items (Centers for Disease Control and Prevention (CDC), 2011).

The most recent published update was the 2009-2010 annual report. This 54 page document highlighted the four key topic areas and their action items. In total there were 53 action items listed. Under topic area two, prevention and control the overarching goal was to develop measures that will decrease the creation of antimicrobial resistant organisms and device strategies to prevent their spread. A few of the highlights of the progress made under this topic area are listed below.

- In 2010 the United States licensed the use of a new pneumococcal vaccine in young children. This vaccine was developed to decrease incidence of antimicrobial-resistant pneumococcal infections. A CDC study is underway to determine its effectiveness.
- The CDC's Get Smart program has developed education materials to educate primary care providers in proper prescribing of antibiotics. This program has provided this material to the Hospital Corporation of America (HCA) and was distributed to primary care practices in New Hampshire and Missouri. The HCA will monitor the prescribing practices in these areas and provide a report to the CDC.
- The CDC will evaluate the Department of Veteran Affairs' National MRSA prevention initiative which has presented their preliminary report and are awaiting peer review. In the preliminary report it was noted that MRSA infection was decreased by 24% in non intensive care unit (ICU) patients and by 77% in ICU patients.

These are just a few examples of progress being made by the IFTAR and the Public Health Action plan to Combat Antimicrobial Resistance (Centers for Disease Control and Prevention (CDC), 2011).

Between 1990 and 2000 the World Health Organization (WHO) convened a series of meetings, workshops and consultative sessions to draft recommendations addressing the expanding public health threat of AR. These recommendations were published as the 2001 WHO Global Strategy for Containment of Antimicrobial Resistance. Sixty-eight priority areas were addressed and centered on seven key groups.

1. Patients and the general community
2. Prescribers and dispensers
3. Hospitals
4. Antimicrobial use in food-producing animals
5. National governments and health systems
6. Industry and research groups
7. International organizations

The recommendations listed in this publication focus on prevention of antimicrobial resistance as a whole and do not highlight specific pathogen directed strategies. The WHO recognizes that will be an individual endeavor of each member state to implement the suggested strategies with the additional need for international interdisciplinary cooperation. The challenge will be to get each member state to understand the relevance and importance of a unified approach toward the prevention and control of antimicrobial resistance. The 58th World health Assembly Resolution on Antimicrobial Resistance 2005 states “despite some progress, the strategy for containment of

antimicrobial resistance has not been widely implemented” (The Fifty-eighth World Health Assembly, 2005).

The National Antimicrobial Resistance Monitoring System (NARMS) was established by the FDA, CDC and U.S. Department of Agriculture (USDA) as a national public health surveillance system. This surveillance system is currently being used to monitor enteric bacteria from food, animals and humans and test the bacterial susceptibility to antimicrobials. This system regularly communicates with other countries’ surveillance systems in order to develop a more cohesive worldwide monitoring system (US Food and Drug Administration, 2011).

Health departments that participate with NARMS send every twentieth isolate of each non-Typhi *Salmonella*, Typhi *Salmonella*, *Shigella* and *E.Coli* 0157 to the CDC laboratory for susceptibility testing. In addition 10 specified states send one *Campylobacter* isolate weekly to the CDC laboratory for the same testing. The data collect is then used to determine trends in resistance patterns and to mitigate efforts to thwart such threats before an outbreak can occur.

Shortcomings of such program could be identified as underreporting and missed resistance in poor sampling numbers. Such shortcomings have not been published in the literature reviewed for this paper (US Food and Drug Administration, 2011).

During World Health Day on April 7, 2011, WHO initiated a worldwide campaign for awareness of AR and to pursue policy change and support in the battle against AR. The Infectious Disease Society of America (IDSA) published a position paper in honor of World Health Day. This position paper was published in the Clinical Infectious Disease Journal and provided a list of policy recommendations to be used in the fight against AR. The paper summarizes the IDSA’s recommendations for how to approach the increasing threat of antimicrobial resistance and the

decrease in approval of new antimicrobial agents. The current recommendations speak to the current system of antimicrobial approval and the need for revisions. The position paper makes recommendations for economic incentives to entice companies to invest in the production of new antimicrobial agents and to revisit FDA procedures in the process of clinical trials in hopes to move the process along more efficiently, while still protecting human health. Recommendations to strengthen federal agency collaboration and leadership, in support of the Strategies to Address Antimicrobial Resistance (STAAR) Act (H.R. 2400 in the 11th Congress) are highlighted, as well as the need for funding for such endeavors (Dellit et al., 2007).

The ISDA's World Health Day policy paper is a more current spin-off of a joint venture between the ISDA and Society for Healthcare Epidemiology of America (SHEA) in 1997. Together these organizations published a position paper based on recommendations formed from their Joint Committee on the Prevention of Antimicrobial Resistance. Similar recommendations are made in both publications with some variations based on the evolution of AR. Sadly, despite recognition of antimicrobial resistance's importance in 1997, 14 years later AR is still a present and ever growing threat to human health and vitality (Natsch, van Kasteren, Kullberg, & van der Meer, 1998).

The remaining focus of this paper will be to review the current literature on the effectiveness of antimicrobial stewardship programs, determine best practices within these programs and establish the feasibility of public health leadership adopting aspects of these programs to develop universal policies, as well as advocate for funding and support to decrease antimicrobial resistance.

Antimicrobial Stewardship Programs

“Antimicrobial stewardship refers to coordinated interventions designed to improve and measure the appropriate use of antimicrobials by promoting the selection of the optimal antimicrobial drug regimen, dose, duration of therapy, and route of administration” (Infectious Diseases Society of America (IDSA), 2011).

Antimicrobial stewardship programs (ASP) were developed to determine the best approach to antimicrobial prescribing, decreasing costs of healthcare, improving patient outcomes and preventing further creation of antimicrobial resistance (Natsch et al., 1998). In 2007, the ISDA/SHEA position paper included guidelines for the development and implementation of antimicrobial stewardship programs. ASP development can vary from institution to institution based on several internal and external factors. However not all approaches are the most effective. A universal approach was the driving force behind the development of the position paper’s guidelines (Dellit et al., 2007). Table 1 illustrates an overview of the general strategies for antimicrobial stewardship programs. Each strategy emphasized is an instrumental component to all programs. This table provides a good summary of the actions needed, personnel required, and the advantages and disadvantages that may be encountered (MacDougall & Polk, 2005). The current literature will be reviewed for best practices in most of these strategies.

Table 1

Summary of antimicrobial stewardship strategies (MacDougall & Polk, 2005, pg 640)

| Strategy | Procedure | Personnel | Advantages | Disadvantages |
|-----------------------|--|--|--|--|
| Education/guidelines | Creation of guidelines for antimicrobial use | Antimicrobial committee to create guidelines | May alter behavior patterns | Passive education likely ineffective |
| | Group or individual education of clinicians by educators | Educators (physicians, pharmacists) | Avoids loss of prescriber autonomy | |
| Formulary/restriction | Restrict dispensing of targeted antimicrobials to approved indications | Antimicrobial committee to create guidelines | Most direct control over antimicrobial use | Perceived loss of autonomy for prescribers |

| | | | | |
|-----------------------|---|---|--|---|
| | | Approval personnel (physician, infectious diseases fellow, clinical pharmacist) | Individual educational opportunities | Need for all-hours consultant availability |
| Review and feedback | Daily review of targeted antimicrobials for appropriateness | Antimicrobial committee to create guidelines | Avoids loss of autonomy for prescribers | Compliance with recommendations voluntary |
| | Contact prescribers with recommendations for alternative therapy | Review personnel (usually clinical pharmacist) | Individual educational opportunities | |
| Computer assistance | Use of information technology to implement previous strategies | Antimicrobial committee to create rules for computer systems | Provides patient-specific data where most likely to impact (point of care) | Significant time and resource investment to implement sophisticated systems |
| | Expert systems provide patient-specific recommendations at point of care (order entry) | Personnel for approval or review (physicians, pharmacists) Computer programmers | Facilitates other strategies | |
| Antimicrobial cycling | Scheduled rotation of antimicrobials used in hospital or unit (e.g., intensive care unit) | Antimicrobial committee to create cycling protocol | May reduce resistance by changing selective pressure | Difficult to ensure adherence to cycling protocol |
| | | Personnel to oversee adherence (pharmacist, physicians) | | Theoretical concerns about effectiveness |

ASP guidelines were also included in the 2011 position paper published by the ISDA for World Health Day. These more current recommendations fall under topic area five: Strengthening Activities to Prevent and Control Antimicrobial Resistance. The ISDA/SHEA ASP position paper emphasizes that universal guidelines and universal acceptance of these guidelines need to be established so that ASPs can be implemented in all settings of healthcare from hospitals of all sizes to private practice and in between (Infectious Diseases Society of America (IDSA) et al., 2011).

One potential setback to the lack of complete success of ASPs is that each program's characteristics and interventions vary on numerous levels, from institution to institution. There is no universal program or universal policing of said programs. Every institution varies in the

administrative support for ASPs and the personnel and financing provided for these programs, creating a lack of consistency among programs. Without mandates, neither requiring ASPs nor financing provided through government programs, a universal approach is unlikely (Infectious Diseases Society of America (IDSA) et al., 2011). The variations among ASP characteristics will be more evident in the results of the systematic literature review of APSs.

Methods

A systematic review of the literature was developed to answer our primary research questions. What are the most effective strategies being used by antimicrobial stewardship programs? Is it possible to form a universal ASP from these proven best practices to be implemented and governed by public health agencies? A literature review was conducted using three databases: PubMed, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and EMBASE. A total of 26 articles for review were ultimately selected following search parameter adjustments as detailed below.

The search terms “antimicrobial stewardship” OR “antibiotic stewardship” was used for PubMed and CINAHL for a return of 309 articles and 102 articles, respectively. The search parameters were adjusted slightly for the EMBASE database, based on the search structure of that database. For EMBASE the search term, “antimicrobial stewardship” OR “antibiotic stewardship” AND ([embase]/lim OR [embase classic]/lim). This search resulted in 441 articles. The search was further limited by the addition of filter to each of the databases. The filters of only English articles, only human research and only research articles were applied to each database with the publishing time parameters of January 1, 2000 through December 31, 2011. This resulted in 92 article matches in PubMed, 12 article matches in EMBASE and 40 article matches in CINAHL.

A quick review of each of the articles for relevance was then performed. Articles that focused on hospital, community or government programs were included. Articles that focused on Clostridium difficile infection or specific organism's resistance patterns or studies were excluded. This then resulted in 31 articles in PubMed, nine articles in EMBASE and 18 articles in CINAHL for a total of 58 articles. All of the selected articles were then uploaded into RefWorks and duplicates were extracted, resulting in a total of 52 article matches.

These 52 remaining articles were then reviewed further for inclusion and exclusion criteria. It was determined that any article that was a research article focused on the assessment of all or a specific aspect of an antimicrobial stewardship program was to be included in this literature review. These included mostly hospital based programs, and some government based programs. Exclusion criteria were articles that were not study based, were not a review of part of or all of stewardship programs or were too focused on a specific pathogen. Articles that focused only on the pharmacist's role and view were excluded. Finally it was decided that inclusion of articles describing guidelines and research on behavioral aspects would be included if they appeared to address important aspects of ASP and could assist in determining best and failed practices to include in the recommendations. This analysis of the research resulted in a total of 18 articles to be included in the final literature review for this paper.

Results

The 18 chosen articles for this literature review were analyzed and broken down into several categories for review. Those aspects of the literature that were felt to be important characteristics of ASPs and were considered key features of the success and failures of said programs were chosen for review categories. The primary goal of the collected data was to make

recommendations based on the current literature for the feasibility and design of a universal ASP initiative to be implemented by public health leadership.

Current Antimicrobial Stewardship Programs

In 2000, Lawton, Fridkin, Gaynes, and McGowan published a cross-sectional survey that was developed to determine the status of programs developed to improve the use of antimicrobials in US hospitals. The participants were staff from 47 hospitals that were taking part in phase 3 of Project Intensive Care Antimicrobial Resistance Epidemiology. They were using the 1997 SHEA/IDSA position paper recommendations as guidance for their programs. It was determined from this study that while all 47 hospitals had some form of a program to improve antimicrobial usage, there was very little consistency in practices among institutions in the study. All institutions included some form of an antibiotic formulary and consultation with a pharmacist or infectious disease physician prior to ordering antimicrobials was required. Recommendations from the SHEA/IDSA position paper indicate that it is not enough to just limit antimicrobial use. Education and guidelines, in addition to monitoring systems, were strongly encouraged. Seventy percent of the hospitals reported having clinical practice guidelines, but dissemination of these guidelines varied among institutions and less than half had a system in place to measure compliance. Lack of consistency among stewardship practices and lack of accountability were highlighted as a prevalent finding among ASPs, despite the 1997 guidelines (Lawton, Fridkin, Gaynes, & McGowan, 2000).

In 2006, Barlam and DiVall, published a study that conducted two surveys looking at the ASP practices. The first survey was used to elicit information regarding ASP practices at 22 top academic medical centers in the United States (US). The second was a mailed survey to 97 teaching and community hospitals throughout Massachusetts. Fifty-four, (56%), of the surveys

were returned and analyzed. Fifteen of the 22 hospitals were chosen for the first survey from the 2001 *U.S. News and World Report*, ranked as “Americas Best Hospitals”. The other seven hospitals were chosen based on their interest and extensive publishing on antibiotic usage and improved practices (Barlam & DiVall, 2006).

The results of the first survey showed that all 22 hospitals had developed some form of antimicrobial stewardship, with an objective of improving antimicrobial dispensing and prescribing. Table 1 provided a comprehensive summary of recommended strategies for ASPs. In comparison of the findings of this study and Table 1; education, computerized assistance, formulary restrictions and antibiotic approval were utilized, however their use varied extensively. Among the fifteen top institutions, nine had widespread antibiotic restrictions and two had no formulary restrictions. Among those with formulary restrictions, infectious disease fellows were responsible for antibiotic approval in nine of the programs. However structured education of these fellows was only provided at one of these institutions. Other programs provided training either through review of approvals with program directors or with a lecture at the start of their fellowship. Only six of the 22 hospitals used computer assistance for antibiotic guidance and approval. There were no measures for feedback or for determining prescribing practice trends in place at any of the institutions surveyed. Finally, funding and support for the studied programs was considered the greatest barrier for all institutions. Despite the presence of these programs, physician compliance and acceptance varied from rare to 85% (Barlam & DiVall, 2006).

In the second survey, it was determined that teaching hospitals in Massachusetts were more active in ASPs activities compared with community hospitals in the state. Antibiotic restriction formularies were implemented in 95% of teaching hospitals as compared to only 49% of the

community hospitals. In teaching hospitals with formulary restrictions, an antibiotic approval process was in place in 94% of these institutions. In the community hospitals only 29% of those with formularies had an approval process (Barlam & DiVall, 2006).

In conclusion of this study, recommendations for multicenter research to identify various effective interventions to reduce antimicrobial resistance were encouraged. The authors believe that these standards should also be included into accreditation agencies requirements, in hopes that administrators will financially and structurally support ASPs (Barlam & DiVall, 2006).

Two more studies conducted in 2009 and 2011 highlighted the variability between ASP programs in similar institutions and lack of regard for recommended guidelines and practices supported by IDSA. In 2009, Hersh, Beekmann, Polgreen, Zaoutis, and Newland published a study that surveyed 147 pediatric infectious disease consultants. This survey again showed a variation in implementation of the programs. First of all, only one third of the respondents reported having an ASP at their facility. Seventy-eight percent reported using a prior authorization, but only one third of those incorporated prospective feedback and review, a foundational tactic in the IDSA recommendations (Hersh, Beekmann, Polgreen, Zaoutis, & Newland, 2009). In 2011, Van Schooneveld, Miller, Sayles, Watkins, & Smith, reviewed ASPs in long-term care facilities in Nebraska. The results revealed that almost 60% of long-term care facilities surveyed in Nebraska had an existing ASP. However, the study determined that despite research and IDSA recommendations, most of these programs were managed by a single person or single discipline (Van Schooneveld, Miller, Sayles, Watkins, & Smith, 2011).

IDSA/SHEA recommendations call for a multi-disciplinary leadership approach to ASPs. The inclusion of an infectious disease physician(s), clinical pharmacists with infectious disease

training, epidemiologist and an infection control professional is considered a gold standard. They also recommend a clinical microbiologist to assist in surveillance (Dellit et al., 2007).

Program Design of ASP

A study conducted by Johannsson et al published in 2011, surveyed physician members of the IDSA EIN. The purpose of the survey was to determine prevalence and attributes of ASPs in the US as well as to determine financial support for these programs. This study revealed that of those responding to the survey, 89% reported involvement with their facilities ASP. It was also ascertained that 91% of those programs also included pharmacists, 33% infection control professionals and 33% microbiologist (Johannsson et al., 2011).

A study at Concord hospital in Australia concluded that 83% of physicians surveyed supported an infectious disease specialist or microbiologist as the best persons to advise antibiotic usage (Bannan, Buono, McLaws, & Gottlieb, 2009). ASP's leadership at the Children's Hospital of Philadelphia included two doctoral level clinical pharmacists and an infectious disease physician. Metjian, Prasad, Kogon, Coffin, and Zaoutis conducted a study published in 2008, at that facility evaluating ASPs in pediatric teaching hospitals. It was found that ASPs were responsible for close to 50% of the antibiotic decision making during the study period and that participants found the guidance useful and effective (Metjian, Prasad, Kogon, Coffin, & Zaoutis, 2008).

Education

Another important aspect of any antimicrobial stewardship program is the inclusion of educational activities. Knowledge drives practice, and it has been shown in the current literature that educational programs have improved adherence to a support of ASPs, specifically by participating medical providers (Dellit et al., 2007).

Charani et al., 2011, conducted a systematic review of the literature from 1999 to April 2011, assessing antibiotic prescribing behavior in acute care settings. The study demonstrated evidence that social norms, beliefs and attitudes influence prescribing behaviors (Charani et al., 2011). Each of these determinants can be influenced through education, however it has been shown that knowledge without active intervention results in marginal changes and effectiveness (Danaher, Milazzo, Kerr, Lagasse, & Lane, 2009).

In 2006 the David Grant USAF Medical center participated in a prospective, randomized study assessing the effectiveness of an education program regarding antimicrobial use. The end-points were defined daily doses (DDD) of antibiotics per patient treatment and days of antibiotic therapy (DOT) per patient treatment. A reduction in both DDD and DOT was observed in the intervention group as compared to the control group:

| | DDD reduction | DOT reduction |
|---------------------------|----------------------|----------------------|
| Intervention Group | 6.7 +/- 7.6 doses | 4.5 +/- 3 days |
| Control Group | 12.9 +/- 16.3 doses | 6.6 +/- 4.6 days |

The reduction of DDDs was statistically significant, with a p-value 0.05 and the reduction of DOTs had a marginally significant p-value of 0.06. Both showed improvement in antimicrobial usage when educational programs were employed (Danaher et al., 2009).

Conversely, it was shown in Van Schooneveld's survey of LTCF in Nebraska that one of the greatest barriers to efficacy of ASPs was noted to be the prescribers' attitudes and actions toward program guidelines. Prescribers were found to have a treat-first attitude, and did not fully understand the impact of antibiotic misuse. Feedback from other healthcare professionals was

not welcomed and routinely rejected. Such actions can easily be attributed to a lack of knowledge or understanding, all of which could be resolved with an effective educational campaign (Van Schooneveld et al., 2011).

Effective Strategies

Various approaches to implementation and execution of ASP have been observed in this literature review. Diverse methods have proven successful in both the reduction of misuse of antimicrobials, as well as generating support and adherence by staff at certain facilities (Bannan et al., 2009; Van Gastel, Costers, Peetermans, Struelens, & Hospital Medicine Working Group of the Belgian Antibiotic Policy Coordination Committee, 2010) .

Concord Hospital in Australia is a 450 bed acute care facility. The ASP in use at Concord hospital requires medical staff to page the Infectious Diseases Unit to receive prior approval of restricted antibiotics. The pager is rotated among infectious disease staff, and if not available, the pharmacists will provide 24 hour dose of prescribed antibiotic but require approval for continuation. The pharmacist supervises observance of the policy and infectious disease physicians counsel departments on correct formularies for specific infections (Bannan et al., 2009).

Bannan *et al.* conducted a survey of junior and senior medical staff to determine their opinions of the current program, concerned with their impact on the future efficacy of the program. One hundred sixty-four surveys were returned out of 440. The results of the survey revealed that 82% had used the system, 98% felt that an antibiotic restriction policy was fair, and that it required careful consideration prior to prescribing. The respondents also reported that they saw the program as a means to reducing antimicrobial resistance (Bannan et al., 2009).

The Belgian Antibiotic Policy Coordination Committee (BAPCOC) has supported the development of antibiotic management teams (AMT) since 2002 by allocating funding, providing technical support and specialist training. In 2010, Van Gastel, Costers, Peetermans, Struelens, and Hospital Medicine Working Group of the Belgian Antibiotic Policy Coordination Committee published a survey of AMT's activities and services in Belgian hospitals in 2007. AMTs are the equivalent of ASPs in the US. They function in an acute care setting to reduce antimicrobial resistance through proper use of antimicrobial agents. In Belgian hospitals it was found that AMTs interacted regularly with both infectious disease specialist and pharmacists. AMTs used multiple means of communication with prescribers as well as made the frequent presence of infectious disease physicians or clinical microbiologists on the floors or at staff meetings. Belgian hospitals supported by the BAPCOC were found to have well defined, structured and comprehensive AMTs. Funding and support from national health care leadership was present and credited with the programs successes. **Table 2** shows a breakdown of the various initiatives implemented at these acute care settings as funding was made available (Van Gastel, Costers, Peetermans, Struelens, & Hospital Medicine Working Group of the Belgian Antibiotic Policy Coordination Committee, 2010).

Table 2

Implementation of antibiotic stewardship initiatives in the acute care hospitals according to the time at which they first received financial support for their AMT and the number of beds, by percentage (Van Gastel et al., 2010, pg 578)

| Antibiotic stewardship initiative | Group A (2002) | Group B (2006) | Group C (2007) | ≤400 beds | 401-800 beds | >800 beds | Total |
|--|---------------------------|---------------------------|---------------------------|----------------------|-------------------------|-------------------------|--------------|
| Antibiotic formulary | 100 | 95.6 | 93.7 | 92.4 | 100 | 100 | 96.3 |
| Guidelines for empirical and aetiological antibiotic therapy | 100 | 91.3 | 85.1 | 90.4 | 90.2 | 100 | 91.6 |
| Guidelines for antibiotic prophylaxis | 100 | 95.6 | 93.7 | 92.4 | 100 | 100 | 96.3 |
| Antimicrobial order forms | 51.4 | 39.1 | 22.9 | 30.2 | 36.6 | 57.1 | 36.1 |
| Requirement of justification and/or authorization for specific antibiotics | 86.5 | 95.6 | 58.3 | 64.1 | 82.9 | 100 | 75.9 |
| Prospective audit with intervention and feedback | 86.1 | 73.9 | 42.5 | 51.9 | 73.2 | 84.6 | 64.2 |
| Automatic stop order | 64.9 | 47.8 | 25 | 37.7 | 46.3 | 57.1 | 43.5 |
| Streamlining or de-escalation of therapy | 75.7 | 73.9 | 50 | 54.7 | 68.3 | 85.7 | 63.9 |
| Parenteral to oral conversion | 86.5 | 91.3 | 66.7 | 81.1 | 73.2 | 85.7 | 78.7 |
| Analysis of antibiotic consumption | 100 | 100 | 91.3 | 94 | 97.6 | 100 | 96.2 |
| Analysis of microbial resistance | 97.3 | 95.6 | 81.2 | 84.9 | 95.1 | 92.9 | 89.8 |

Electronic antibiotic stewardship was studied by Buising *et al* in 2006 in a teaching hospital in Melbourne Australia. Using a computerized approval system for antimicrobial use, prescribing practices, resistance patterns and patient outcomes were analyzed. The study was able to show that a computerized approval system that is designed by knowledgeable clinicians is an effective avenue for prescribing. The system was accepted by providers. A positive change was observed in antibiotic prescribing habits and a noted decrease in resistant strains of *Pseudomonas spp.* and *S. Aureus* occurred (Buising et al., 2008).

Finally, care bundles are defined as a group of actions based on evidence- that are employed for a specific period of time. Their inclusion into ASPs was reviewed in a study conducted by Toth, Chambers, and Davis, published in 2010. The care bundle in this study was defined as the intervention of a clinical pharmacist in patient care. The clinical pharmacist worked with the medical team in the direct care of patients receiving selected antibiotics. The pharmacist's role

was to monitor the patient's cultures and antibiotic therapy, suggest appropriate changes to antimicrobials and to conduct four to five education sessions a month focusing on the facilities resistance and susceptibility profiles. The control group was a retrospective review the year prior of patient outcomes and susceptibility using the same antimicrobials and patient inclusion criteria. The study was looking at care bundle's impacts on compliance in an acute care center. It was determined that compliance with quality indicators such as documentation of treatment rationale, collection of cultures and appropriate empirical and definitive antimicrobial usage with the cessation of antimicrobials if no infection is found, improved dramatically with the introduction of care bundles. Compliance rates were found to increase from 16% to 43% with a p value of < 0.001 (Toth, Chambers, & Davis, 2010).

Barriers

Barriers to effective stewardship programs have also been identified in the current literature. Johannsson et al published a study in April 2011 focused on the evolution of strategies and barriers. This study surveyed members of the IDSA EIN who care for adult patients and received a 50% response rate. Primary barriers for the success and implementation of an effective ASP identified by physician members were lack of funding, lack of administrative support, limited provider compliance, inadequate or absent technical support and higher priority clinical initiatives. Table 3 shows data from the study on ranking of barriers from most common (1) to least common (7). Lack of funding, lack of personnel and administrative support were ranked the most prevalent barriers to developing and effective program. Approximately 50% of the respondents reported that they received no compensation for their involvement in their institutions ASP. Additionally, hospital administrative support was found to be lacking in most hospitals where cost saving was considered the primary goal of the programs, despite the proven

cost effectiveness of ASP (Johannsson et al., 2011); (Dellit et al., 2007). One study showed a 32% decrease in expenditures on antimicrobials after the initiation of their ASP, as well as a significant reduction in resistance (White et al., 1997)

Table 3

Rank Order of Barriers to a Functional and Effective Antimicrobial Stewardship Program (ASP)(Johannsson et al., 2011 pg 371)

| Barrier | No ASP | | Planned ASP | | Current ASP | |
|--|--------|---------------|-------------|---------------|-------------|---------------|
| | Median | Mean \pm SD | Median | Mean \pm SD | Median | Mean \pm SD |
| Lack of funding or personnel | 2 | 2.2 \pm 1.6 | 1 | 1.4 \pm 1.0 | 1 | 2.3 \pm 1.7 |
| Other higher-priority clinical initiatives | 3 | 3.1 \pm 1.7 | 3 | 3.0 \pm 1.6 | 3 | 3.1 \pm 1.5 |
| Administration not aware of value of ASP | 3 | 3.0 \pm 1.7 | 3.5 | 3.5 \pm 1.8 | 4 | 4.0 \pm 1.8 |
| Opposition from prescribers | 4 | 3.6 \pm 1.7 | 4 | 3.8 \pm 1.7 | 3 | 3.3 \pm 1.8 |
| Lack of informaton technology support and/or inability to get data | 4 | 4.4 \pm 1.9 | 3 | 3.7 \pm 1.8 | 4 | 4.0 \pm 1.9 |
| Other specialties antagonized by ASP | 4 | 4.0 \pm 1.6 | 5 | 4.7 \pm 1.7 | 4 | 4.1 \pm 1.8 |
| Multiple infectious disease groups within facility | 7 | 5.3 \pm 2.3 | 7 | 6.2 \pm 1.4 | 7 | 5.9 \pm 1.9 |

Note No barriers were reported by 3 respondents with a planned ASP (5%) and by 38 respondents with a current ASP (13%). Rank: 1, most common; 7, least common.

Several other studies have identified similar barriers to implementation and effective utilization of ASPs. Provider compliance is a major issue noted in a few studies assessed in this literature review (Hersh et al., 2009; LaRosa et al., 2007; Van Schooneveld et al., 2011)). LaRosa et al describe “stealth dosing” in a cross sectional study published in 2007. Antimicrobial ordering was assessed at an acute care hospital that had a prior-approval time period for ordering targeted antibiotics. Prior approval for antibiotic ordering ended at 2200 hours each evening, resuming in the morning. This study assessed orders that occurred between the hours of 2100-2159 and the orders that occurred from the hours of 2200-2259. It was determined that more of the antibiotic orders between 2200-2259 hours were for restricted medications than those that were ordered from 2100-2159 hours. It was also determined that more of the antibiotics ordered after the prior approval time frame were deemed inappropriate and discontinued than those ordered during the prior approval periods (LaRosa et al., 2007).

Site Specific ASP Reviews

Systematic literature review also produced four studies that assessed antimicrobial stewardship in specific hospital settings. These included emergency departments, intensive care units and pediatrics units. All four studies identified practicality and effectiveness in each of the settings, with an improvement in antibiotic use found in the ICU. (Acquisto & Baker, 2011; Hersh et al., 2009; Kaki et al., 2011; Metjian et al., 2008). Stewardship programs in the pediatric setting were found to be few. Of those programs in existence, it was shown that most did not monitor end points such as compliance rates, redundant therapy or improper antibiotic usage. In this same study, 50% of the 147 pediatric infectious disease consultants did not feel that antibiotic resistance was an issue at their hospital, despite 80% of the same respondents stating resistance was a national crisis issue (Hersh et al., 2009).

Kaki et al. conducted a systematic review in 2010 assessing the effectiveness of ASPs in the critical care setting. The results of the study showed a positive decrease in antimicrobial usage, a decrease in hospital stays per patient, less money spent on antimicrobials and shorter duration of antimicrobial administration. Additionally, ASPs were not associated with an increase in mortality or hospital acquired infection rates. Limitations of this study were based on the few research studies conducted on the topic, but a positive outcome in ASPs in critical care settings was seen from the analysis of their literature (Kaki et al., 2011).

Government ASPs

The current literature was also reviewed for studies that focused on government enforced and supported ASPs. Four studies were identified in the systematic search. Van Gastel et al's study was able to profile comprehensive ASP's that had impressive support both financially and

structurally. In addition, the study emphasized that with such support effective programs can be developed (Van Gastel et al., 2010).

In 2011, Dumartin et al published two studies that assessed trends in antibiotic use with ABS measures in south-western French hospitals and their associations. These studies were conducted between 2005 and 2009. Health authorities in France support the development of ASPs in acute care centers and a legal framework was established by the French Ministry of Health for the development of ASPs (Dumartin, Rogues, Amadeo, Pefau, Venier, Parneix, & Maurain, 2011a). The Dumartin studies also concluded that with the right amount of personnel, multidisciplinary staff and governmental support, antibiotic use is better controlled (Dumartin, Rogues, Amadeo, Pefau, Venier, Parneix, & Maurain, 2011b).

Multiple endeavors supporting antimicrobial stewardship have been undertaken in Europe. A study by Allerberger, Gareis, Jindrak, and Struelens published in 2009, reviewed hospitals' APS's initiatives and their objectives. Standards of these programs are outlined, and the use of these standards by accreditation bodies as framework for support of ASPs was recommended. Again an interdisciplinary team is suggested for leadership of the programs and education is highlighted as a key to gaining provider support. Barriers in Europe are identified as similar to those in the US, including funding acquisition and appropriately trained staff to manage the programs. The study concludes that successful implementation of stewardship programs require dealing with three major gaps: (1) further research to determine cost effectiveness of ASPs and to determine effectiveness of differing approaches; (2) development of evidence-based best practices through expert consultation and research and (3) enhancing legal basis and funding for antimicrobial stewardship programs (Allerberger, Gareis, Jindrak, & Struelens, 2009).

Discussion/Future Direction

“In 1967, U.S. Surgeon General William H. Stewart told a White House gathering of health officers that ‘it was time to close the book on infectious diseases and shift all national attention (and dollars) to what he termed ‘the New Dimensions’ of health: chronic diseases’” (Forum on Microbial Threats, 2006). Over the past four decades since that statement, 37 new infectious human pathogens have been identified. Additionally, 12 known infectious human pathogens threaten human health through re-emergence (Mueller, Merrell, Grimm, & Falkow, 2004). In 2001, infectious disease had a worldwide mortality rate of 26% (Forum on Microbial Threats, 2006). The “book” appears to have a sequel, one that is far from being finished.

Antimicrobial resistance was actually recognized prior to the FDA approval of penicillin. In the September 1945 publication of Miscellany News this quote was taken.

“Dour, white-thatched Sir Alexander Fleming, discoverer of penicillin, is fearful of the consequences of uncontrolled distribution of his ‘baby.’ In a recent interview Sir Alexander remarked that there was danger of ‘educating the microbe to resist penicillin.’ In his talk at a dinner tendered him by penicillin producers and the following evening he again referred to this fear. ‘The greatest possibility of evil in self-medication is the use of too small doses so that instead of clearing up the infection, the microbes are educated to resist penicillin and a host of penicillin-fast organisms is bred out.’ But he went on to express the hope that this danger could be averted”(Miscellany News, 1945, pg 153).

Even in the 1940s it was known that misuse of antibiotics could lead to antimicrobial resistance, but it was not until 1997 that recommendations for surveillance, prevention and control were published. Hence, we are now faced with an enormous public health threat that is a global issue, because antimicrobial resistance knows no geographic boundaries. Such a colossal task cannot be effectively handled by individual organizations. Public health leaders need to take a firm position concerning this and, just as in the early twentieth century, direct us to an era where microbes are in our control. The IHR would be the most suitable organization to regulate efforts

for a global approach, but many barriers still need to be addressed. Although antimicrobial stewardship programs are just one variable in the battle against antimicrobial resistance, they could be our greatest defense (Infectious Diseases Society of America (IDSA) et al., 2011; Miscellany News, 1945).

A systematic review of the current literature on ASPs shows that although guidance is available, most current programs leave much to be desired. In addition there does not appear to be any universal oversight, specifically in the United States (Barlam & DiVall, 2006; Lawton et al., 2000). Multiple studies have proven repeatedly that misuse and over use of antimicrobials are the primary avoidable causes to resistance (Cohen, 1992; Craig et al., 1978). This must be our focus, and the best approach is through a standardized program for surveillance, prevention and control. ASPs are a valuable start in that venture.

Although autonomy is regarded as a right by health care providers, the threat of AR is too great to ignore a necessarily structured approach to the problem. Policy and law should to be developed in order that an objective and effective treatment program can govern antimicrobial use for the betterment of mankind. The objective is to cause a decrease in antimicrobial resistance, an increase in susceptibility, and the development of more antimicrobials for our treatment arsenal. Although a global approach would be ideal, each country needs to take responsibility for such action to start. In the U.S., public health leadership, such as the HHS and CDC should administer resistance programs at a government level. They should be responsible for eliciting support from higher officials, both financially and structurally. Public health leaders at the national level should guide research based on current local, national and global resistance trends, continue to assess interventions, and maintain compliance from individuals and institutions.

The literature shows us that it will be difficult to enforce one set of guidelines (Dellit et al., 2007; Lawton et al., 2000). Healthcare institutions are unique to their setting, environment, culture and size. This is true of resistance patterns as well. Acute care settings differ from community and private practices and each health care practitioner has his or her own set of beliefs and preferential treatment modalities. Autonomy is a hallmark of practice as a physician or advanced practice provider, and most practitioners would not easily abandon this autonomy lightly. These factors highlight the complexity of a universal program. Despite all of the above, it is still a possibility. The current literature reveals some very effective strategies, successful government managed and supported practices and highlights the challenges (Dumartin, Rogues, Amadeo, Pefau, Venier, Parneix, & Maurain, 2011a; Van Gastel et al., 2010). Much is already known, but need to be organized and accepted in order to move closer to a successful program applicable to all.

It was shown in Van Gastel's study focusing on Belgian hospitals in 2007, that a successful program can be developed and undertaken effectively with strong support and backing from government health officials (Van Gastel et al., 2010). In review of the current literature key elements were highlighted as being themes influencing successful programs.

- Sufficient funding
 - Provides the means necessary to develop programs as well as compensate the specialists and staffing required to support the programs.
- Administrative backing
 - A successful program requires administrative support for the necessary resource allocation, as well as for collaborative leadership.
- Wide scale education

- Education of staff, community partners and the general population is required for a comprehensive understanding of strategies, the issue at hand and corrective actions. Education also assistance with compliance rates.
- Compliance from healthcare providers
 - In order to decrease antimicrobial resistance proper use of antimicrobials is necessary. Compliance of healthcare providers with current recommendation is at the heart of proper antimicrobial usage.
- Multidisciplinary leadership for each program
 - A multidisciplinary approach provides expertise from various specialties. In addition collaborative efforts assist in sharing the workload in managing the programs.
- Technological support and availability
 - Computer assisted programs provide antimicrobial guidance, management, decision-making feedback and training programs. This allows for a larger audience reached in a timely fashion.

Diverse approaches can and should be developed to meet the complex nature of healthcare. No single system will work for all. As a set of strategies achieves the endpoint of decreasing AR and increasing susceptibility, then they should be included in future guidance. Continual searches for new and effective approaches will only assist in assuring future success.

The Public Health Core Competencies were published as guidance for the set of skills required for public health professionals to possess to be successful in the delivery of essential public health services. A review of the essential public health services only enhances the argument that

the coordination and enforcement of ASPs is an essential public health role (Council on Linkages Between Academia and Public Health Practice, 2001).

- Monitor health status to identify community problems
- Diagnose and investigate health problems and health hazards in the community
- Inform, educate and empower people about health issues
- Mobilize community partnerships and action to solve health problems
- Develop policies and plans that support individual and community health efforts
- Enforce laws and regulations that protect health and ensure safety
- Link people to needed personal health services and assure the provision of healthcare when otherwise unavailable
- Assure an expert public health workforce
- Evaluate effectiveness, accessibility, and quality of health services
- Research for new insights and innovative solutions to health problems

These skill sets enable public health professionals with the knowledge and ability required for such an endeavor (Council on Linkages Between Academia and Public Health Practice, 2001).

In 1988, the Institute of Medicine published *The Future of Public Health*. This report highlighted the importance of public health leadership development. In response to this report the CDC established the National Public Health Leadership Institute and provided funding for state and regional leadership institutions (Saleh, Williams, & Balougan, 2004). In addition to the Public Health Core Competencies, leadership education and training has made a major impact on public health practice. These programs improve upon the skill sets of public health workers and their

ability to create positive and effective changes to health programs (Leadership Development National Excellence Collaborative, 2001).

The National Public Health Leadership Development Network, under HHS, developed the Public Health Leadership Competency Framework as a guidance tool for assessing leadership skills and developing training programs. This framework focuses on four core competencies; transformational competencies, political competencies, trans-organizational competencies and team building competencies. Within these four core competencies are subsets of skill sets that enhance each core mission (National Public Health Leadership Development Network, 2005).

- Core Transformational Competencies
 - Visionary Leadership
 - To develop and share an embodiment of innovative ideas for future directions and to encourage others to share this vision
 - Sense of Mission
 - The personification of values, beliefs and ethics and the facilitation of mission development
 - Effective Change Agent
 - Optimizing learning, critical thinking and analytical skills through creative means.
 - Facilitates these changes into practical situations
- Political Competencies
 - Political Process

- Identification of policy issues and the development of alternative avenues to implement public health programs
- Negotiation and Mediation
 - Mediation and guidance through public health crises through investigation and resolution
 - Identification of key stakeholders and resources
- Ethics and Power
 - The identification of power-based alliances and collaborative actions with an ethical and value-based framework
- Marketing and Education
 - The utilization of social media to communicate with and educate target audiences
- Trans-organizational Competencies
 - Organizational Capacity and Dynamics
 - The creation of assessment models to assess organizational environment, their needs and assets and identifies opportunities all in relation to a specific mission and vision
 - Trans-organizational Capacity and Collaboration
 - The inclusion of key stakeholders, players and personnel in collaborative efforts
 - The development of partnership strategies, such as, task forces, coalitions and teamwork activities
 - Social Forecasting and Marketing

- Identifies emerging trends and predicts scenarios to act upon
 - Utilization of social media for communication
- Team building Competencies
 - Team Structures and Systems
 - Develops and drives team building activities and promotes organizational learning
 - Creates ownership and pride amongst the team members
 - Team Development
 - Clear goals and objectives
 - Shared mission and values
 - Develops problem solving, conflict resolution and decision making skills within the members
 - Facilitation and Mediation
 - Establishes team member roles
 - Mentors and coaches team members
 - Effective Role Modeling
 - Models listening, negotiating, encouraging, motivating, integrity, credibility, enthusiasm, trust and commitment

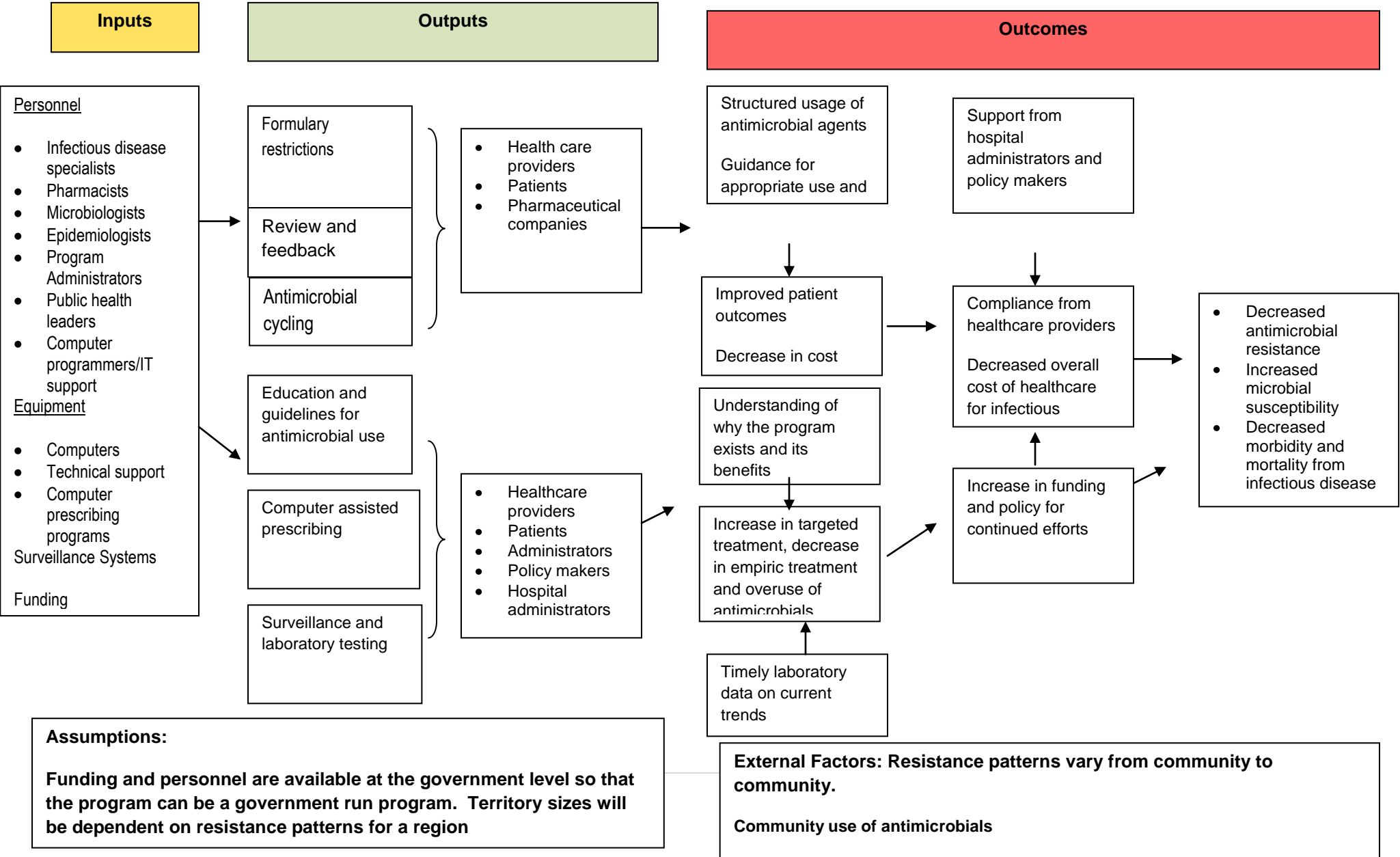
Each of the above skill sets provides solid leadership abilities to initiate and enforce antimicrobial resistance programs. Additionally, the application of collaborative leadership has been shown to be an effective strategy for making a positive impact on public health programs. Collaborative leadership uses supportive methods to ensure that all individuals impacted by a decision are included in the change process. This approach empowers many, allowing for

strength in numbers (Leadership Development National Excellence Collaborative, 2001). With relation to ASPs, a collaborative approach would, minimally, include leadership from hospital administrators, infectious disease physicians, pharmacists, laboratories, and a public health task force. Together these leaders would need to take on the mission of decreasing antimicrobial resistance through proper antimicrobial usage. Guidance has been provided for the development of ASPs, however each participant in the program should be encouraged to actively participate in the development of such a program. Public health professionals should lead this initiative utilizing the leadership skill sets set forth by the Public Health Leadership Network Development. Task forces can be created to develop best practices related to the development of a universal ASP. A facilitator from the public health departments can lead each group acting as both a mediator and a visionary, empowering each group to complete each task with ownership and pride. The development of such a program will be challenging but with strong leaders at the helm, nothing is impossible (Leadership Development National Excellence Collaborative, 2001; National Public Health Leadership Development Network, 2005).

Below is a logic model created from the current literature review in this paper. It incorporates best practices identified in the literature and is suggested as a model to guide future development of ASPs. As stated already, many barriers exist towards the development of a set of universal stewardship programs but the skill sets required to manage such a task have already been proven by past and current public health endeavors, led by public health leaders.

Figure 2 is a Logic Model of Antimicrobial Stewardship Program development for public health leadership. It was designed based on the evidence from the literature review for this paper.

Program: Antimicrobial Stewardship Situation: *Need for universal program employed by Public health leadership as guidance for appropriate antimicrobial usage based upon antimicrobial resistance patterns*



Conclusion

Antimicrobial resistance's impact on mankind is yet to be truly determined. It is known that in times prior to the use of antibiotics and the understanding of hygiene, infectious disease was the number one killer (Centers for Disease Control and Prevention (CDC), 2011). We appear to be moving backwards to a time before antibiotics were developed.

Public health leaders have played an essential and influential role in the dramatic decline of mortality from infectious diseases in the past century and more, and should be called upon now to do the same. Many challenges still face the public health sector but proven successful public health initiatives, such as tobacco regulation, seatbelt safety, clean air acts and sanitation have shown that it is possible for public health to lead our nation towards a resolution (IOM (Institute of Medicine), 2011). The scope of AR is enormous and therefore, revisions to public health policy and statutes will most certainly require revision providing public health leader's authority over antimicrobial use. Healthcare institutions will need to follow such mandates to gain better control over this evolving issue.

Many local, government and worldwide public and health organizations have identified AR as an increasing global threat for a number of years. Each entity has made recommendations and has devised efforts to address the problem but somehow we remain unable to adequately apply solutions. One approach is the requirement for ASPs. Although national guidance for such programs has been provided, too many variables have been left up to interpretation and too much leeway has been given in the development of programs. This is the greatest challenge before us as we move towards a concrete solution. Although public health practitioners are more than capable of coordinating and policing a set of universal antimicrobial stewardship programs, they

will require assistance and collaboration from other health care professionals to create comprehensive and effective programs. Additionally, funding and resources need to be directed towards preventive efforts (Centers for Disease Control and Prevention (CDC), 2011; Infectious Diseases Society of America (IDSA) et al., 2011; IOM (Institute of Medicine), 2011; World Health Organization, 2011).

We should recognize where that 80% of the increase of life expectancy and quality in our populations during the 20th Century has been as a result of the public health practices of disease prevention, promotion of healthy behaviors and protection against health risks (Centers for Disease Control and Prevention (CDC), 1999). We should institutionally provide the support necessary to maintain those amazing, achievements!

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